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To: A. J. Murphy, A. M. Kammerer, U.S. Nuclear Regulatory Commission

Subject: ***Comments on Draft Regulatory Guide DG-1146, A Performance Based Approach to Define the Site-Specific Earthquake Ground Motion***

Provided below are comments on the subject Draft Regulatory Guide

In October 2006 the United States Nuclear Regulatory Commission (NRC) published Draft Regulatory Guide DG-1146, *A Performance Based Approach to Define the Site-Specific Earthquake Ground Motion*, for public comment. Section 4 of DG-1146 states "that the proposed action will reduce unnecessary burden on the part of both the NRC and its licensees, while improving the process for siting of nuclear power plants." Because of vague terminology and lack of appropriate guidance on what constitutes an appropriate probabilistic seismic hazard analysis (PSHA), implementation of DG-1146 could well result in an unstable regulatory process, with protracted debate on PSHA related issues.

DG-1146 outlines new methods for defining a site-specific performance based Safe Shutdown Earthquake (SSE), using the approach described in Chapters 1 and 2 of American Society of Civil Engineers (ASCE) Standard 43-05, "*Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities.*"

One of the most important criterion for evaluating the acceptability of a performance-based approach is the suitability of the seismic hazard assessment to support the determination of an appropriate probabilistic seismic hazard used as part of the ASCE 43-05 process to meet the selected target performance goal (expressed as a target mean performance criterion of $< 1x10^{-5}$ per year for the frequency of onset of significant inelastic deformation). It is important that any regulatory guidance provide regulatory stability, particularly with respect to potential changes or updates of the input parameters for probabilistic seismic hazard analysis (PSHA).

Use of a site-specific mean 10^{-4} annual probability level to define the uniform hazard response spectrum (UHRS) as the starting point, based on the precedent set in ASCE 43-05, depends on the stability of PSHA results for a given site. While two divergent mean PSHA curves can be used to meet an intended target performance goal, each may result in widely different design ground motion levels or SSE. Divergent PSHA curves with different slopes could also result in different values for the ASCE 43-05 "design factor".

DG-1146 Vague PSHA Terminology

In three places DG-1146 uses the phrase "accepted probabilistic seismic hazard studies" (see Section B pages 3 and 4, Appendix C page C-1), without defining what these studies are. On page 5 DG-1146 refers to two PSHA studies (Electric Power Research Institute {EPRI} and Lawrence Livermore National Laboratory {LLNL}), and states that "these databases **may** still represent the latest information available for **some** seismic sources" (emphasis added). In section C 1.1, page 10, the text discusses situations where new data or interpretations are not adequately incorporated **into the existing PSHA database** (emphasis added), without defining what these databases are. It is not clear how such language will improve the process for siting of nuclear power plants.

When NRC developed Regulatory Guide 1.165, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion", one of the objectives was to achieve regulatory stability. At that time a decision was made to use the concept of "reference probability", established in part where the EPRI and LLNL PSHA results were found to provide consistent ground motion values. The reference probability was selected as a median 10^{-5} annual probability. It is important to note that selection of a mean annual probability (for example that needed to support a performance-based approach) for the "reference probability" was not possible, in part, due to wide differences between PSHA results based on EPRI and LLNL.

Completion of a PSHA for a given location should be based on the latest seismic hazard information which depends on the geological and seismological setting of that location. One of the original motivations that NRC had for developing the LLNL results was to provide for an independent check on PSHA results derived by applicants, to ensure that the probabilistically derived ground motion levels were appropriate for seismic design purposes. Such a check and balance should be an explicit part of regulatory oversight to ensure that PSHA results provide an appropriate assessment of seismic hazard.

Because of the divergent EPRI and LLNL PSHA results, NRC, along with the Department of Energy and EPRI, sponsored development of "Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts", published as NUREG/CR-6372 (commonly referred to as the Senior Seismic Hazard Analysis Committee or SSHAC report). The sponsors of this work saw a need for more stability in the PSHA process. While both the EPRI and LLNL PSHAs were landmark efforts, neither of these studies was completed following the SSHAC guidelines, and thus could be legitimately challenged in terms of providing the necessary regulatory stability for application following the approach found in ASCE 43-05.

Efforts to update either study (such as what has been completed to support Early Site Permit {ESP} applications) needs to be reviewed carefully to ensure that all PSHA input represents the current state of seismologic and geologic practice. It appears as if the trend is to update EPRI PSHA results and ignore past LLNL results. While the technical basis for this trend is not clear (other than the implication that applicants like the lower EPRI PSHA results), it appears to be supported by DG-1146, based on the precedence from Regulatory Guide 1.165 even though that

reference was not linked to a performance based approach which requires an accurate absolute estimate of probabilistic seismic hazard.

Comprehension PSHA studies have been completed by the United States Geological Survey (USGS) as part of the national seismic hazard mapping project, with results published in 1997 and 2002. The USGS work is being updated for release in 2007. The information and data from the USGS work provides important insight into how the informed scientific community views the assessment of many seismic hazard issues. While some issues are obvious, such as paleoliquefaction findings near Charleston, South Carolina, New Madrid, Missouri, and Wabash Valley, Illinois, other issues are more subtle, such as the preference for smoothed seismicity versus detailed definition of area seismic sources in low seismic hazard environments. The USGS PSHA work is not discussed in DG-1146. The USGS PSHA work can not be ignored given that it represents the most recent comprehensive PSHA work for the United States.

The implication from the above discussion suggests that NRC should be capable of performing confirmatory PSHA assessments as part of their regulatory oversight. It is not clear whether NRC has maintained the capability to execute a "LLNL PSHA" for a given site location as part of their regulatory review and oversight. NRC needs to recognize that different organizations could execute the EPRI, LLNL or USGS PSHA methods for a given location, which could result in widely divergent design ground motions following the approach found in ASCE 43-05. Without addressing these issues it is not clear how regulatory guidance will result in regulatory stability.

To compound these issues, the recent submission of the Vogtle ESP application, Site Safety Analysis Report, further demonstrates that PSHA stability does not exist. Consistent with other ESP applications (North Anna, Grand Gulf, Clinton), the Vogtle applicant has chosen to use an update to the EPRI PSHA to assess seismic hazard and establish appropriate ground motion for seismic design. The update to the EPRI PSHA for Vogtle, however, is significantly different than the EPRI PSHA work used by the preceding three ESP applicants, and inconsistent with material provided by EPRI as part of the ongoing dialog regarding resolution of seismic hazard issues[(1)]. Specific issues related to the EPRI PSHA update used for Vogtle are provided following the remaining comments.

Appendix D provides a procedure to determine controlling earthquakes. Step 1 of this procedure states that the site-specific PSHA should be conducted at a minimum of 30 frequencies, approximately equally spaced on a logarithmic frequency axis between 100 and 0.1 Hz. DG-1146 provides no basis that a minimum of 30 frequencies are needed to accurately assess the uniform hazard spectra. This implies that a PSHA will require ground motion attenuation models at each of these frequencies, which is not within the current state of practice. While there may be a need to assess closely spaced frequencies in certain situations, such as higher frequencies (> 10 Hz) for hard rock sites, it will not be necessary for many situations in terms of accurately assessing the uniform hazard spectra.

DG-1146 supports the development of rock-based PSHA results, using generic hard rock conditions. Appendix E states that generic hard rock conditions are associated with a shear wave velocity of about 2.8 km/sec (9,200 ft/sec). The basis for defining generic hard rock at a shear wave velocity of 9,200 ft/sec is not provided and is inconsistent with other published definitions of hard rock based on shear wave velocity (see for example FEMA Report 450-1, 2003 Edition of National Earthquake Hazard Reduction Program Recommended Provisions for Seismic Regulations for New Buildings and Other Structures, where hard rock is defined by a shear wave velocity of > 5,000 ft/sec). Additionally it is not clear why an applicant in the Western United States would be required to generate a PSHA for hard rock site conditions when this shear wave velocity may only exist at deep depths.

Appendix E provides guidance related to seismic wave transmission analysis including section E.3, Site Response Analysis. The NRC sponsored a comprehensive study of ground motion related issues, published as NUREG/CR-6728, *Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard and Risk Consistent Ground Motion Spectra Guidelines.* Chapter 6 of NUREG/CR-6728 describes procedures for developing hazard consistent spectra on soil, and provides 4 approaches for developing soil ground motions. While Appendix E of DG-1146 provides useful guidance on site response related issues, the approach for developing soil ground motions represents only 1 of the 4 approaches from NUREG/CR-6728 (approach 2). This would suggest that NRC does not encourage any of the other 3 approaches described in NUREG/CR-6728. Section E.3 of Appendix E should be expanded to provide guidance for completing soil ground motions following approaches 3 and 4 from NUREG/CR-6728.

<u>Specific issues related to the EPRI PSHA update used for Vogtle ESP application, Site Safety Analysis Report</u>

- The Charleston seismic source is modeled using four possible source delineations applied to each of the EPRI seismic source teams. Modification of the EPRI team(s) Charleston sources, by necessity, requires modification of other sources (given that the revised Charleston source areas no longer match the aerial extent from the EPRI expert teams). This implies that the seismic sources beyond Charleston also need revision, not just to fill the aerial gap, but because Charleston is more restricted, with more frequent large earthquakes, judgments regarding nearby seismic sources would likely also change. The aerial gap was addressed by allowing portions of "old" EPRI source zones that lie outside the new replacement Charleston source zone to default to the existing EPRI background zones for each team. Why such an approach is assumed to represent the informed technical community, based on seismic source definitions that are about 20 years old, is subject to debate. To maintain the PSHA process the expert teams should be the ones to agree to these adjustments. This change by itself implies that the updated EPRI PSHA results are inconsistent with the SSHAC process and objective of representing the informed scientific community (versus the views of the applicant's contractor).

- A key argument for not revising much of the EPRI team seismic sources relates to lack of paleoseismic evidence and stability of seismic activity rates outside of Charleston. Such a conclusion strongly suggests that there would be little technical basis for modifying the LLNL expert seismic sources in those locations. The basis for ignoring the LLNL seismic sources in terms of representing views of the informed scientific community has not been provided.

- Review of the USGS PSHA input suggests that there is much less scientific community support for aerial seismic sources beyond those locations which have paleoseismic evidence for large prehistoric earthquakes in the central and eastern United States (CEUS). It is not clear why applicants would not be required to incorporate this information into their PSHA work, especially given that this seismic source input is much more recent compared to those portions of the EPRI or LLNL PSHA based on seismic source input from the 1980's. Additionally, differences between EPRI and USGS for the Charleston seismic source should be evaluated.

- Review of EPRI PSHA input for the southeast US indicates that at least one team has areas where there is no host seismic source zone for a large percentage of the time (Dames and Moore team, seismic source 53, Southern Appalachian Mobile Belt). When this zone does not exist (probability of activity = 0.26) there does not appear to be a replacement seismic source zone. It is not clear that such a view represents the informed scientific community today, especially given the information contained in the USGS national seismic hazard map. Review of the USGS PSHA input to the national map indicates that no location in the CEUS should be judged as having no local seismic hazard. The recent moment magnitude 6.0 earthquake in the intraplate region of the Gulf of Mexico provides additional evidence that moderate sized earthquake can occur anywhere. A complete technical review of the EPRI PSHA input is needed before it should be supported as providing adequate input for a mean PSHA assessment.

- Application of the USGS PSHA code for hard rock site conditions for the Vogtle site location would likely show different mean PSHA results for all annual probability levels. Any differences between EPRI and USGS should be evaluated in detail, to determine if both results can be supported and should be used to represent mean PSHA derived ground motions. The figure provided below compares uniform hazard spectra for a return period of 10,000 years between the Savannah River Site (USGS results) and the Vogtle site (modified EPRI results) both for hard rock site conditions, suggesting the PSHA stability does not exist.

Summary

In summary, any updated regulatory guidance that adopts the ASCE 43-05 approach must address those steps that will result in PSHA stability to ensure overall regulatory stability. Use of pre-existing PSHA results (adjusted or not) and/or recent USGS PSHA results requires more study before such regulatory stability can be defined. Adjusting either the EPRI or LLNL PSHA input may not be feasible given that much of the original work for both of these studies is now about 20 years old. This implies that a comprehensive PSHA update for the CEUS may be needed. The USGS should play a prominent role if this step is taken to ensure appropriate integration of PSHA input parameters with the national seismic hazard map. Finally, NRC should be encouraged to

retain the capability to perform independent PSHA confirmatory calculations (as they had with the LLNL PSHA code) as part of their regulatory review.

(1) Program on Technology Innovation: Assessment of a Performance-Based Approach for Determining Seismic Ground Motions for New Plant Sites, V1 Performance-Based Seismic Design Spectra, V2 Seismic Hazard Result at 28 Sites; EPRI Technical Reports (1012044 and 1012045).